INTEGRATED WAREHOUSE - ASSEMBLY LINE RETRIEVAL SYSTEM

by

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CERTIFICATE

t is to certify that the work contained in this thesis entitled "INTEGRATED WAREHOUSE - ASSEMBLY LINE RETRIEVAL SYSTEM" by Mr M V S Gopala Krishna (Roll No 9411414) has been carried out under my supervision and hat this work has not been submitted elsewhere for a degree

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ABSTRACT

The work on this project was motivated by the production planning problem of a major automobile company The project involved planning and scheduling of resources (fork lift and trolley attached trucks) for the material transfer from central warehouse to assembly stations In this company, vehicles are assembled on assembly line, which runs continuously Frame (chassis) of the vehicle is mounted on the first station of the assembly line, and it leaves the system with the vehicle ready for the dispatch, from the last station

Parts and subassemblies are assembled on the chassis at relevant assembly stations as the conveyor of assembly line moves These parts and subassemblies are stored in five types of standard size bins in central warehouse which is at a distance from the assembly line So these parts are to be transfered to the required assembly stations for the assembly purpose In this thesis, we integreate the material requirement planning at the assembly line with the order pick up system at the warehouse

We developed a integrated database management system, which takes as input the batch production requirement at the assembly line, computes the material requirement time schedule for each component at each assembly station, generate trips and transportation schedule for the equipment transporting material between warehouse and assembly line and links it with the order pick up system in the warehouse The order pick up system for given set of pick up requests, selects the optimum location in the warehouse for the material retrieval, generate the schedule and tour for the pick up equipments to optimize the retrieval cost

CHAPTER I

INTRODUCTION

1.1 Introduction

The work in this dissertation is motivated by the warehouse problem of a major automobile company The company has recently established a new plant and the facilities are under construction In this company, vehicles are assembled on a assembly line, which runs continuously Frame (chassis) of the vehicle is mounted on the first station of the assembly line and it leaves the system with the vehicle ready for despatch, from the last station Parts and subassemblies are assembled on the chassis at relevant assembly stations as the conveyor of assembly line moves Parts and subassemblies are stored in five different types of bins in central warehouse, which is at a distance from the assembly line So these parts are to be transferred to the required assembly stations for the assembly purpose It was decided that , fork lifts and trolley attached trucks should be used for this purpose As fork lift can carry only one bin at a time, it was decided that fork lifts should be used for the larger capacity bins Similarly trolley attached trucks are assigned to smaller capacity bins as each truck can carry more than one bin depending on the capacity (floor space) of trolley

Reddy N J M [1] worked on optimizing the number of fork lifts and trolley trucks to be used for transferring parts from the central warehouse to the assembly stations for the assembly purpose Agarwal K [2] has extended Reddy's work and considered a different module of the overall problem of warehousing, in which storage and retrieval costs, incurred while storing and retrieving various items inside the central warehouse, are to be minimized Rohit Bansal [68] has developed an on-line information system to facilitate efficient and fast operation of the warehouse

On the receipt of the production schedule for the batch, it is required to compute the parts and subassemblies required at various assembly stations and number of bins of that part / subassembly to be transferred to that work station and the time by which this transfer should be completed Each of the bin transfer from the central warehouse to the assembly station is considered as a job and each job is executed on a material handling equipment according to their due-dates Therefore, to make the processing of the jobs fast and efficient, an on-line information system is needed, which can help warehouse manager in deciding an optimal policy for scheduling the material handling equipment and retrieval of items in the warehouse The basic objective in deciding on an optimal policy, typically, is to minimize the overall cost incurred on material handling equipment and in retrieving the items in the warehouse The system should also be capable of monitoring the performance of various resources of the warehouse, so that necessary changes can be made in the policies to meet the changing requirements of the organization

1.2 Warehousing

In the past few years, the field of warehousing has begun to receive attention that it deserves. However, the warehouse manager has been repeatedly asked to increase customer service and productivity, to reduce inventory, to handle large number of stock keeping units and to improve space utilization in the warehouse

The function performed by the warehouse as studied in Tompkins J A and Smith J D [67]are.

- Receiving the goods from the stores
- Storing the goods until they are required
- Picking the goods when they are required
- Shipping the goods to the appropriate user

Warehouse planning is not simply pouring a concrete slab, installing some racks, and tilting up some walls, it is static one time activity The changing dynamic environment in which warehouse are planned, quickly renders existing plans obsolete Therefore we need an on-line dynamic system in which warehouse planning is a continuous activity and the existing plans are constantly being scrutinized and molded to meet anticipated requirements A successful warehouse maximizes the effective use of the limited warehouse resources while satisfying customer requirements

The following objectives must be met for a warehouse to be successful

- Maximize the effective use of space
- Maximize the effective use of equipment
- Maximize the effective use of labor
- Maximize the accessibility of all items
- Maximize protection of all items

In warehousing a distinction is made between a finished goods warehouse and a raw materials storeroom The only true distinction between the two are the sources from which the goods are received and the user to which the goods are shipped A raw material storeroom receives goods from the outside source, stores the goods, picks the goods, and ships the goods to an inside user A finished goods warehouse receives the goods from an inside source, stores the goods, picks the goods, and ships the goods to an outside user Similarly, an in-process inventory warehouse receives goods from an inside source, stores the goods, picks the goods, and ships the goods to an inside user Our problem is mainly concerned with the raw materials storeroom and in-process inventory warehouse

Warehousing for the purpose of commercial gains is at least as old as recorded history In early writing, man was described as having stored excess food and kept animals for emergency surplus As civilization developed, local warehouses were introduced When major trade points were introduced during middle ages, warehousing was

established to store the shipped items All the developments stressed more upon the warehouse location and connection with the external sources and demand points But as warehousing systems advanced from local warehouses during the middle ages to multi-million dollar facilities, more attention was being paid towards what is going inside the warehouse

Computer directed warehousing systems using stacker cranes and palletized loads have revolutionized the design and capacity of high volume, large capacity storage facilitates Now more attention is being paid towards saving labor costs, high floor space utilization, improved material flow, improved inventory control, and a lower incidence of misplacement or theft Maximized benefits of such a system are dependent upon the optimal design of the system, that is, operating cost of warehouse (Storage and retrieval costs and time) (Tompkins J and Smith J D[67])

1.3 Literature Review (review of previous work)

There has been quite a number of studies on various aspects of automated warehousing systems and optimization algorithms for scheduling material handling equipment Four various classes of this literature are given below This literature is taken from Reddy N J M [1], Agarwal K [2] and Rohit Bansal [68]

1.3.1 Optimization Algorithms for completion time based Parallel - Machine

Hu [51] introduced a label scheduling algorithm, also called the critical path method, to solve a set of non-preemptive in-tree unit jobs, in O(n) time Hu's algorithm first labels the level of the terminal job as zero which implies that the terminal job should be the last job to be processed Then, according to the set of partial orders of other jobs, these jobs are labeled with the highest level that they may have Highest level jobs have the highest priority to be processed on he first available machine The level of a job is

defined as the length of the longest path from that job to the terminal job Hu's approach is called "highest level first"

Chen and Liu [31] generalized Hu's algorithm to deal with non-preemptive partial order unit jobs on an arbitrary number of machines Their algorithm requires the partial order of the jobs to satisfy the condition that the number of independent jobs in the sets of immediate successors is always less than the number of machines, it yields an optimal schedule in O(n) time

Fujii et al [53] investigated the problem of a set of unit jobs with arbitrary precedence relations to be processed on two machines Their algorithm orders a set of disjoint compatible job pairs by a matching technique Thus, the number of pair wise disjoint compatible job pairs is maximized Any pair of jobs i and j is defined as compatible if both jobs are free from any precedence relation so that they can be processed on two different machines simultaneously The algorithm runs in $O(n^3)$ time

Coffman and Graham [42] applied the highest level first algorithm for arbitrary precedence relation problems for a set of non-preemptive unit jobs The algorithm breaks ties with jobs in the same level in a way entirely different from Hu's algorithm Rather, if a job contains a lower lexicographic of the labels of the immediate successors, it has a higher processing priority For the two machine case, the algorithm produces an optimal make span in $O(n^2)$ time Garey and Johnson [37] developed another algorithm to examine whether there exists a feasible schedule for two processors for a set of arbitrary precedence relation unit jobs with general due-date requirements The approach of their algorithm is to combine the set of partial orders of jobs and the modified due-dates of each job

Gabow [27], based on the idea of highest level first scheduling, developed a new algorithm for a set of partial order jobs for the two machine problem Davida and Linton [45] showed that the highest level first algorithm developed by Hu is equally applicable to out-tree scheduling problems with sets of non-preemptive unit jobs

Any set of non-preemptive jobs can be viewed as a special case of set of preemptive partial order jobs Hence, if a non-preemptive scheduling problem is shown to be NP-complete (Garey and Johnson [37], Ullman[29]) Along this line, Muntz and Coffman [30] applied the level algorithm to solve the two machine preemptive scheduling problem The algorithm runs in $O(n^2)$ time and yields mn preemptions Another p called "fast-schedule-by-weight" was introduced by Gontzalez and Johnson [48] to compare with Muntz and Coffman's algorithm for the same two machine preemptive scheduling problem The new algorithm runs in O(n log m) time with no more than n-2 preemptions

A general dynamic programming scheme has wide applications for most scheduling problems The scheme for the minimum make span problem is given in the paper by Graham et al [49] Another dynamic programming scheme is given by Leung [58]

1.3.2 Optimal order picking problem

The order picking problem is the complementary of the above problem where orders are received and the optimal sequence for picking these orders is to be found Phillips [54] used the network concept as a basic analytical technique solving order picking problems In his technique, he considered the nodes of network as locations of items while the distance between two locations is presented as an are value Chisman [35] proposed several methods for picking orders Orders are divided into three groups, batch carrier, line batch and order picking batch In carrier batch, geographic similarity of the orders is the main criterion for assigning the orders to such a group A line-batch group includes all the items which are placed on one shipping line prior to loading on a truck, while the order-picking-batch includes all the items placed on one pallet as a bin-packer passes through the warehouse Chisman [35] suggested two methods for bin picking · SN-picking (Stock Number Picking) and BL-picking (Bill-of-loading picking) He stated that the choice between SN-picking and BL-picking is a matter of

whether one wants to or finds it cheaper to sort out BL's at the bins or in the shipping line The solution to this problem was obtained by using a cluster traveling salesman algorithm developed by Chisman [35]

Elsayed E A [26], presented four heuristic algorithms for handling orders in automatic warehousing warehousing systems The algorithms select the orders that will be handled in one tour in order to minimize the total distance traveled by the S/R machine within the warehouse system Computer programs are developed for the four algorithms and the optimal tours are found by using the traveling salesman algorithms Optimal or near optimal tours are found for the handling problem The conclusion reached was that optimum policy is problem dependent Thus, he suggested, for a given problem it is better to evaluate all the policies and pick the one that provides the best results

Elsayed E A and Stern R G [38], presented some new algorithms for processing a set of orders in automated warehousing systems The proposed algorithms will process the orders by grouping the orders according to some criteria developed by authors They proposed four *seed selection* criteria, three *order congruency* criteria and two *order addition* criteria. Thus, they suggested 4*3*2 = 24 possible algorithms for the order picking problem The traveling salesman algorithm is then utilized to determine the optimal distance traveled within the warehouse for every group of orders Comparisons of the performance of the proposed algorithms are also presented The proposed algorithms proved to be data dependent and were sensitive to the capacity of the picking vehicle

Hwang H, Wonjang B and Moon Kyu Lee [39], presented heuristic algorithms for batching a set of orders such that the total distance traveled by the order picking machine is minimized These algorithms were based on the cluster analysis and their efficiency and validity were illustrated through computer simulation. The results obtained were found to be better than those from the previous studies

Goetschalckx M and Ratliff H D [40], presented a special case in which items have to be retrieved manually from both sides of a wide aisle and deposited on a vehicle which travels on the center line of the aisle The picker will stop the vehicle, pick and load the cases of items onto the vehicle and then drive to the next stop They presented an algorithm to determine the optimal number and location of stops and specify the items to be picked at each stop

Hwang H and Moon Kyu Lee [39], dealt with order processing problem in a man-on-board automated storage and retrieval (AS/RS) system They presented new heuristic algorithms based on cluster analysis The algorithms process the orders by batching them according to the value of similarity coefficient which is defined in terms of attribute vectors To find the minimum travel time for each batch of orders, the traveling salesman algorithm is employed The results obtained through computer solutions indicate that some of the developed algorithms performed substantially better than those of the previous studies

1.3.3 Throughput maximization problem

Azadivar F [62], in his paper attempted to determine the maximum number of storage and retrieval requests that can be handled by automated warehousing systems under physical and operational constraints He formulated the system as a stochastic constrained optimization problem and developed an algorithm for its solution The constraints involved were limits on the average waiting time for retrieve requests and the maximum queue length for the items waiting to be stored Due to the stochastic nature of the operation of the system, a simulation model was constructed to evaluate the system for various values of its parameters

Azadivar F [28], presented a method for the optimum allocation of the resources between the Random Access spaces and Rack spaces so that the overall throughput

capacity of the warehouse is maximized He formulated and solved the problem as a stochastic optimization problem

1.3.4 Warehouse design problem

Hwang H and Chang S Ko [43], suggested a Multi-Aisle S/R machine system (MASS) which can substantially reduce high initial investment cost which is a major reason for the low popularity of AS/RS in manufacturing companies The objective of their study was mainly related to the design aspect of MASS With a travel time model developed they determined the average travel time of the S/R machine They proposed rack-class-based storage assignment procedure and class selection procedure to find out the minimum number of S/R machines required and to identify the number of aisles each S/R machine serves The procedure applied to example problems showed that MASS is effective in reducing initial installation cost, provided that the pallet demand is relatively low

Park Young H and Dennis B Webster [55], developed an optimization procedure to aid a warehouse planner in the design of selected three dimensional, palletized storage systems All the alternatives were compared in the overall model while simultaneously considering the following factors control procedures, handling equipment movement in an aisle, storage rules, alternative handling equipment, input and output pattern for product flow, storage rack structure, component costs review reveals that there is an abundance of potential research area that deserve further study

1.4 Present Work

In this dissertation, as has been stated, problem of assembly line - warehouse integration for a large automobile plant will be dealt with Here, an attempt to develop an on-line information system has been made, which can facilitate smooth and efficient

functioning of the warehouse The basic objectives of the information system are as follows

- to make the handling and execution of batch requests fast and efficient
- to optimize the number of material handling equipment used for material transfer from warehouse to assembly stations
- to provide all the information about the assembly stations and warehouse, instantly
- to reduce the time taken to procure the material from the warehouse and transfer them to the assembly stations
- to find out the utilization of various resources of the warehouse

In chapter II, first the problem environment has been described followed by a discussion on the problems like - due-date calculation, material handling equipment optimization - both fork lift and trolley trucks and the order picking problem Finally underlying assumptions have been stated in order to make the problem environment in which the system has been developed, more clear

Chapter III provides a detail insight to the problem structure as a whole and its solution Here, the methodology, which has been adopted in solving different problems of due-date calculation, material handling equipment optimization and the order picking problem, are discussed

In Chapter IV, a detailed description of the steps involved in the evolution of the information system is given It describes flow of necessary data in the warehouse and a detail description of the data requirement for the development of the system It also includes a brief description of the procedures, adopted in the system, for a assembly line retrieval request The functionality of the information system, as a whole, has been described here with the help of the flow charts The different hardware and software requirements of the information system are also mentioned here

Chapter V, essentially, is a user manual which describes the information system from the user point of view. It includes the description of various menu systems and their

functioning and various options available to the user for the processing of a request It also describes the data requirements, format of the data and the way to enter necessary data into the system for a smooth and trouble free functioning of the system Different type of outputs generated by the system and their interpretation is also discussed in this chapter It also describes how to install the warehouse information system at the user's side

In Chapter VI, the developed system is used on two randomly generated problems, the impact of batch sequencing

In Chapter VII, a critical appraisal of the above mentioned information system is done along with the possible improvements in it In addition, some possibilities of further expansion of the present system are discussed

CHAPTER II

PROBLEM DESCRIPTION

2.1 Description of the problem

In section 1 1 the motivation for this work has been described As stated, the work on this dissertation was motivated by the production planning problem of a major automobile company The company has recently planted a new plant and the facilities are under construction The project involved planning and scheduling of resources (fork lifts and trolley-attached trucks) for the material transfer from central warehouse to assembly stations

In this company, vehicles are assembled on assembly line, which runs continuously Frame (chassis) of the vehicle is mounted on the first station of the assembly line, and it leaves the system with the vehicle ready for the dispatch, from the last station Parts and subassemblies are assembled on the chassis at relevant assembly stations as the conveyor of assembly line moves These parts and subassemblies are stored in five types of standard size bins in central warehouse which is at a distance from the assembly line so these parts are to be transferred to the required assembly stations for the assembly purpose It was decided that, fork lifts and trolley attached trucks should be used for this purpose As fork lifts can carry only one bin at a time, it was decided that fork lifts should be used for the larger capacity bins Similarly trolley attached trucks are assigned to smaller capacity bins as each truck can carry more than one bin at a time depending on the capacity (floor space) of trolley

Some of the salient features of the production system are detailed next The company, presently, produces 4 - 6 models of vehicles, but has plans of producing at least 20 different models Each model requires different parts subassemblies, but some are

common to other models also Each part may be required at more than one station Same part which is required at a particular station for a particular model may be required at another station for another model The data regarding list of parts and number of each part required per vehicle for each model and at the assembly stations it is required is available Each station has a sufficient capacity to accommodate reasonable amount of inventory Once a part or a bin is brought to the station it is not returned back to the central warehouse at the end of the day, if not used It lies at the station until it is consumed for the assembly operations Let us assume that a vehicle production schedule (batch schedule) is available i e the data regarding the number of vehicles to be produced and the type of model for each batch is known in advance Present practice with the company is to have such a plan available for a specified period in advance of the actual scheduled production To model the problem we shall assume that components / materials required for production are transferred by bins to the assembly stations Further the sizes of the bins and their quantity for a component which it can carry are standardized Hence all the requirements of the component / material are expressed by numbering such required loads and are referred to by bin numbers. Hence from now onwards we shall refer to such component / material load by its bin number Transportation of each such bin shall be treated as a job in machine scheduling notation Further, we shall associate with each bin, required to meet the production schedule, a time element referred to as its 'due-date' This due-date is the time by which this bin should reach the desired station in order to avoid the stoppage of the assembly line due to shortage of part Now the aim is to schedule the fork lifts and trucks such that each part reaches the desired assembly station before the assembly line is stopped due to the dearth of that part In the process, we have to make use of minimum possible number of fork lifts and trucks such that there is no need to buy more It is also desired that they should be efficiently utilized

2.2 Due-date Calculation

2.2.1 Factors for due date computations

[1] Fork lifts and trucks start operating before the first batch is scheduled for production Due-date depends on this time difference

[2] The station at which the bin is needed (since it takes time for the chassis to reach that station from first station This time is Zero for the first station)

[3] Sequence of the batches and the composition of batches

[4] The amount of time it takes to consume the inventory of this part that is already lying on the assembly station

Generally the conveyor runs with constant speed, and that speed is known aprion The assembly stations are situated at equal distances on the assembly line The assembly stations are situated at equal distances on the assembly line The time taken for the fork lifts and trucks to travel from the warehouse to the assembly stations and back can be calculated (This includes the time of loading and unloading of the bin which we shall assume to be constant) This time is referred as processing time for the job in scheduling terminology

The scheme for computing due-date for a part is as follows as descibed in Reddy N J M [1]·

2.2.2 Scheme for computing due-dates:

Step [1] Consider the first part / component i e $k = 1$, first batch i e $i = 1$, first station i e $j = 1$ Also count = 0, where count indicates the number due-dates that have already been generated

Step [2]. Initialize all due-dates to the amount of time that is available for the fork lifts or trucks before the actual commencement of first batch occurs

Step [3] Calculate the total number of parts of type k that are needed for batch i and station j Let it be tparts

Step [4] If inventory on station j for kth part (inventory[j, k]) is greater than or equal to tparts then

(i) decrement this inventory by tparts i e

inventory[j, k] = inventory[j, k] - tparts,

(ii) set tparts to zero, increment the index of station

i e j = j+ 1,

(iii) if station index is greater than number of stations then

set station index[j] to 1, increment batch index[i] by one,

(iv) if batch index is greater than the number of batches then go to step6 else go to step [3],

Step [5] If inventory on station j for the part (k) is lesser than tparts then

(i) increment count by one,

(ii) generate due-date with index count, due-date is equal to sum of the time taken for the chassis to reach from first station to the j th station, time taken for the consumption of the inventory lying on the station, and time at which i th batch is commenced for production, (If fork lift and trolleys start to operate before the assembly line begins to operate then add this time difference also.),

(iii) decrement tparts with the product of the maximum number of vehicles that can be produced with the inventory on station j for part k and the number of parts needed per vehicle,

(iv) set inventory equal to the left over inventory after it is consumed for producing maximum number of vehicles that can be made with the inventory that was lying on the station, increment the inventory with the number of parts that can be carried in a bin, go to step [4],

Step [6] increment the part index k by one,

if the part index is greater than the highest index of parts then STOP

else go to step [3]

These due-dates provide deadlines for the respective parts to reach their respective assembly stations to avoid stoppage of production First we shall solve the problem assuming that the vehicle production schedule (batch schedule) is available and it is fixed However we shall examine the impact of batch sequencing on the requirement of the fork lifts and trolleys as well as their deployment This will help in developing algorithms for sequencing of batches to efficiently utilize the material handling equipment

2.3 Material Handling Equipment Optimization :

This problem, essentially, is to decide the number of material handling equipment to be used to transfer the inventory from warehouse to the various assembly stations for assembly purpose Whenever a batch requests comes to the warehouse, the system should be able to divide the whole inventory transfer into number of jobs and generate their due-dates The criterion here can be the optimal allocation of these jobs on to various Material Handling Equipment so that the due-dates of each job can be fulfilled and the number of equipment used can be minimized

Again, when many types of equipment are there, it is to be decided that what equipment will carry which item to which assembly station When equipment can handle more than one bin at a time, the assembly stations and items which should be served in a particular tour have to be decided When more than one job is there, then keeping the due-date constraint in mind, the starting date of the jobs can be decided

2.4 The order picking problem

The order requests for the assembly line based on the trip schedule will give rise to the order picking problem in the warehouse Whenever a retrieval request comes to the warehouse, the system should decide an optimal sequence for picking the items listed in the request from their respective storage locations Here also there may be several

cases depending upon the type of the request menu Retrieval request may be of a single bin of an item or it may be a menu comprising of several bins of an item The objective criterion will be minimization of the retrieval distance or time

Again, when many type of equipment are there, then it is to be decided that which equipment will retrieve which item from which location When equipment can handle more than one bin at a time, the locations and items which should be served in a particular tour have to be decided When more than one retrieval requests are there, then keeping the due-date constraint in mind, pick up orders can be formed from actual orders i e items from two or more actual orders can be clustered together to form a pick up order to be retrieved in a single tour

2.5 Problem Classification

The problem of transportation of material from warehouse to assembly line can be broadly classified into two major categories depending upon the type of transporting equipment - fork lift type (i e can handle only one bin) or trolley type (i e can handle more than one bin) Further each of these two categories can be further subdivided on the basis of whether the bins are retrieved in batches or only a single bin handled at a time, within thw warehouse

2.6 Assumptions

In this section, all the assumptions are listed which have been made while formulating the problems and designing the information system The assumptions are

- The warehouse in consideration is a rectangular warehouse with an input dock and several output docks There are several aisles parallel to each other The row space is continuous
- Bin sizes are standardized and are integral multiple of unit size

- Each bin holds only one type of item at a time
- Entire contents of the bin are retrieved at a time
- Several types of equipment are there, with constraints on the type of bins they can carry and the locations which they can serve
- In the following, job refer to a bin transportation and machine to the transporting equipment
- Equipment (Machines) are never kept idle while work is waiting
- There are no precedence relations between jobs
- A job can be processed on any machine
- The equipment acceleration and deceleration time is ignored

CHAPTER III

SOLUTION METHODOLOGY

The main objective of this dissertation is to develop a computerized system for the management of assembly line and production system and integrating with the warehouse The mathematical structure and the solution methodology for this problem has been discussed by Reddy N J M [1] Further warehouse retrieval system has been described by Bansal R [68] The aim of this dissertation is to integrate the two modules i e Assembly line production - Transportation system with warehouse retrieval system First we shall describe the problem of material transportation for the warehouse to the assembly line and then the salient features of warehouse retrieval system

3.1 Assembly line - warehouse transportation system

The input to the problem are batch schedule, Bill of Material for each model type, Requirement of component at the Assembly stations for various models and details of the equipment available for the transportation from warehouse to assembly line

As outlined in Section 2 2, for the given batch schedule for each of the part at each of the assembly line stations a due date i e the date (time) by which the material should reach at these stations in bin load is computed Every such requirement is treated as the Job in machine /scheduling terminology These jobs are required to be processed on machines (transportation equipment) and the processing times is the time required for loading, unloading and travel from warehouse to the assembly stations The core problem encountered in this systen is machine optimization (i e fork lift type or trolley optimization) problems

In the next section we quote the methodology used to solve these problems from Reddy N J M [1], which we have used in development of our system

3.1.1 Fork lift Optimization

The inputs of the problem are the jobs with due dates and the processing times, which also depended on the travel time of the equipment between the assembly stations The travel time between the assembly stations is being considered though it can be ignored when compared with the travel times from warehouse to assembly stations as well as loading / unloading times

3.1.1 ALGORITHM (Modified-EDD)

Input Jobs with J_1, J_2, J_3, , J_n with d_1, d_2, , d_n and processing times P_1, P_2, , P_n

3.1.1.1 Description of Algorithm

Step 1 - Arrange all the jobs in the ascending order of their due dates

Step 2 - Assign the job on the top of list to the lowest index machine

Step 3 - If the job is found late on the machine indexed i, schedule the job on the machine with index i + 1 If the job is again late repeat the step 3

Step 4 - If the job is not late, remove the scheduled job from the list and go to step 2

3.1.1.2 Implementation of the Algorithm

Here in the implementation of the algorithm, nomachines represents number of machines, noofjobs is number of jobs, minnoofmachines is minimum number of machines that are required, noscheduled[j] is number of jobs scheduled on machine j, machine[i, j] represents the index of job that is scheduled on ith machine in jth position of the sequence,

Step 1 Sort the jobs in EDD order

Step 2 nomachines = 1, i = 1, count = 1 (* i is the index of the job *) Initialize the completion time of all the machines (completemach[i]) to zero

Step 3 count = 1

Step 4 If completemach[count] + p[i] > d[i] then

count = count + 1

If count > nomachines then

noofmachines = noofmachines + 1

goto Step 4

Step 5 completemach[count] = completemach[count] + p[i]

noscheduled[count] = noscheduled[count] + 1

machine[count, noscheduled[count]] = i

i = i + 1,

Step 6 If i > n then minnomachines = nomachines, STOP

else goto Step 3

3.1.2 Trolley Optimization problem

Here, in the trolley optimization problem, for a group of jobs scheduled on a single trolley, the due-date of that group is the earliest due-date of the any job in that group of jobs The jobs are required to be scheduled on the machine so that they are completed before their due-date which implies that batches on machine can be scheduled in their due-date order (EDD Schedule)

3.1.2.1 Algorithm (Modified-EDD)

3.1.2.1.1 Description of the algorithm

Step 1 - Sort the jobs in EDD order

Step 2 - Construct the groups using first fit bin packing algorithm (which implies that jobs are selected in serial order and assigned to the earliest bin to which they

can be accommodated, keeping in view the space requirement or the capacity of the bin In case they cannot be accommodated in the existing bin a new bin is started)

Step 3 - Calculate the due-dates of each group Due date of a group is the due-date of that job whose due-date is minimum among the due-dates of all jobs in the group

Step 4 - In the due-date order groups of jobs are assigned to the first machine on which they can be scheduled without the job being tardy If no such machine is available a new machine is setup

Step 5 - Step 4 is repeated till no jobs are left

The above algorithm is basically designed on the same lines as the algorithm for the fork lift optimization problem

3.2 Warehouse retrieval system

The other major component of the system is warehouse retrieval system The core problem in this system is, identification of location for retrieval and order pick up schedule for retrieval In the next sections we quote some salient features of the system from Rohit Bansal [68]

3.2.1 Distance Computation

Distance between two locations and between input or output docks and a specific location is an important measure as the cost of retrieval and cost of storage is dependent on these measures Distance function, required to describe these distances will vary from application to application To provide flexibility, a generic function has been selected which is capable of modeling most of the distance measurements by setting up of parameters In practice, in warehouses the movements of the equipment will be along an aisle(horizontal movement), across an aisle (horizontal movement) and

along the height of racks (vertical movement) However, in some cases it is possible to move the equipment along the shortest path (Euclidean distance) such as across the racks The generic function, selected for distance computation, provides for

(a) Different weights to be assigned for computation of travel times in the horizontal, vertical and across the aisle movements as the speed of equipment will differ for each of such movement

(b) Across the aisle movement can, generally, take place, either at the beginning or at the end of the aisle and accordingly, to access a location in another aisle, the equipment has to move either to the beginning or to the end of aisle

(c) In the case of vertical movement in the same aisle, the movement can be of one of the following type

- the equipment has to be moved to the ground position and then again to the appropriate height after the required horizontal movement
- the equipment can be moved horizontally without changing the vertical position and hence vertical distance moved will be the difference of the vertical location of the two points
- in some cases, the pick up arm can be moved across the rack along the shortest path

The generic function which is selected for computations purpose is given below in mathematical form

$$d_{ij} = [\, H \{\, d\,|X_i - X_j|^a + e * \min [(X_i + X_j), (2 * L - X_i - X_j)\,]\,\} + A|Y_i - Y_j|^b + V \{\, \{\, f\{Z_i + Z_j) + g|Z_i - Z_j|\}^c \}\,]^d$$

Where

H is the weight for horizontal distance

V is the weight for vertical distance

A is the weight for across the aisle distance

L is the length of the rack along the aisle

X_i, X_j are the x-coordinates of locations i and j, along the aisle

Y_i, Y_j are the y-coordinates of locations i and j, across the aisle

$Z_i + Z_j$ are the z-coordinates of locations i and j (vertical movement)

a, b, c, d are the constants to determine the type of distance function, that is, rectilinear, Euclidean or squared Euclidean

e, f and g are the dependent binary variables which take value 0 or 1 to select the appropriate horizontal movement

In order to minimize the cost of transporting different items from or to the storage locations in the warehouse, distance traveled by an equipment from one location to the other is found Also the distance traveled by the equipment from dock to first location and then the returning distance to dock is also calculated These distances are computed using the distance function discussed above

3.2.2 Retrieval Cost : This is the cost incurred while retrieving an item or bin from a particular storage location in the warehouse to a specified output dock It includes the transportation cost and the labor cost incurred by the equipment while transporting the item from a storage location inside the warehouse to the output dock from where the item is to be shipped It is a function of location from which the item is to be picked, equipment used for transporting and the output dock at which item is to be shipped

3.2.3 Solution methodology for order pick up in the warehouse

After the jobs are assigned on various machines, now the problem comes to the order pick up from the warehouse In order pick up problem, the request is of retrieval type in which there is a list of items or a single item which are to be picked from the warehouse. Here, the only cost involved is retrieval cost which is incurred because of

equipment movement Therefore the objective here is to minimize the distance traveled to execute a retrieval Below, a general method to solve the order picking problem is given

Step 1. System Initialization

User is required to specify different inputs regarding the warehouse structure (location numbers, aisles etc), the distance function, the cost function, the list of available equipment or a single equipment with their characteristics Here it is to be noted that this step is not performed every time a request is submitted to the system It may be executed in part, either in the form of specifying a different cost function or a different distance function

Step 2. Order Pickup Input

This request is taken from the user (here user is the assembly line) with all necessary details like list of the items which are to be retrieved from the warehouse and their quantities Since the equipment is to be selected by the user, the list of equipment to be used for different items is also taken, from the user And also the time constraints for execution of the request, which is in the form of due-date is also taken

Step 3. Item Availability Check

A check is performed whether the specified items are available in desired quantity or not It is done with the help of quantity ordered for the item and the stock level of item in the warehouse If any item is not available in the warehouse in desired quantity then that item is discarded from the request and appended in the wait queue

Step 4. Location Availability List

For each item, listed in the request, a list of those storage locations is found where the item is stored in the warehouse

Step 5. Location assignment

From the location availability list , locations from which the order has to be picked up, are selected This step may be executed differently for different problems

Step 6. Equipment Tour

The sequence of retrieving the items from the warehouse is found In determining the sequence of retrieval, the objective is not only to minimize the cost of retrieval but also to minimize the number of equipment trips needed for retrieval

Step 7. Equipment Schedule

After determining the sequence of operation for every tour of each equipment selected, time taken by the equipment in each tour is computed This is the time taken by the equipment in traveling to all the storage locations in a particular tour plus the unloading time of bins at the selected locations and the loading time at the receiving dock The loading and unloading times are function of the type of equipment and the type of bin handled by that equipment

Step 8. Output Generation

In this step, all the results, which are arrived at in the above nine steps, are summarized and delivered to the user It includes which item is to be picked from which location, which are the bins to be moved and which equipment is to be used for retrieval purpose and bin transfer to the various assembly stations It also provides the sequencing of retrieval operation for each equipment in each tour

Here, in the system, the equipment is specified by the user before submitting the request to warehouse Therefore, system need not to select the equipment for any item listed in the request Here, the above mentioned steps Location Selection and Equipment selection will be executed under the below given constraints

Constraint 1: the specified equipment for the item should be able to access the location i e height of the location should be less than or equal to the accessible height of the equipment

Constraint 2: the specified equipment should be able to handle the type of bin which is stored at that location

In the above procedure for locations assignment, the locations are arranged in the ascending order of the cost associated with them And the locations are selected from the top of list for the specified item The number of locations selected from the list depends upon the quantity ordered for the item The above mentioned methodology is repeated for each type of item listed in the request

CHAPTER IV

SYSTEM SPECIFICATION AND DESIGN

This chapter covers the systematic way in which the Integrated Warehouse - Assembly line retrieval system has evolved out of the problem discussed in chapter II It covers the entire development phase of the system, right from conceptual design upto the actual design The chapter is broadly divided into two parts First part is system specification, in which the system is described conceptually with the help of data flow diagrams, structured specifications of the processes involved and data required for the system In system design part, actual design of the system is described which consists of the design of the underlying database, program flowcharts, and input and output design of the system

4.1 System specification

4.1.1 Data flow diagram :

The brief data flow diagram, along with the description of the processes involved, for the warehouse information system is shown in figure 4 1

The requests are sent to the warehouse by assembly line (termed as retrieval requests) for the delivery of items In this, request is processed by the system and the processing instruction is given to the warehouse personnel to execute the request physically The processing instructions include the necessary equipment(s) to be used with in the warehouse, the warehouse locations which are to be accessed, the assembly stations which are to be served, the sequence in which theses locations are to be accessed, and the material handling equipment to be used for transferring to assembly line

A detailed data flow diagram of the Information system is shown in figure 4 2 It illustrates the step by step procedure of executing a batch request sent to the warehouse The brief description of all the processes involved in the procedure are given below

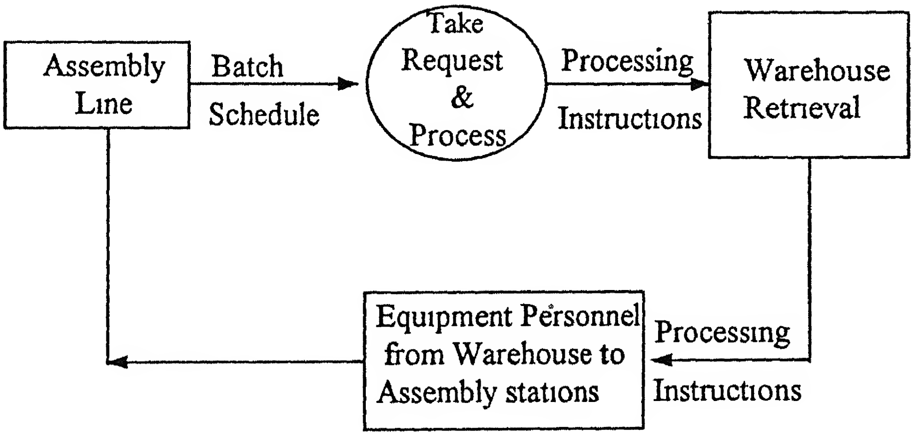

Fig 4.1 Data Flow Diagram

Process 1 : The various functions of Process 1 are

- to take a batch request and all its details, e g batch no , type of model, quantity of model, starting date of the batch etc
- to generate details of the request and to send these details to Process 2

Process 2: The functions of Process 2 are

- to check the incoming batch request with the batch master file to ensure that two requests do not have the same batch number
- to ensure that the type of model listed in the request is valid It is done with the help of the model master file

Process 3 : In this process, the batch request file is updated with the details of the current request

Process 4 :

- according to the type of model, bin requirements of each item at various workstations and their due dates are calculated This can be done by using files- assembly station requirements, parts information at assembly stations and process details
- to send the part requirement information Process 5

Process 5 : The functions of process 5 are

- for each part requirement information check the bin capacity information and accordingly calculate the number of bins of parts to be transferred to the assembly station
- make each of this bin transfer, a job and send this information to Process 6

Process 6 : The functions of Process 6 are

- for each job in job details list, find the equipment and assign the job until the job is not delayed
- send this information to Process 7

Process 7 : In this process, order pickup request file is updated with the details of the current request

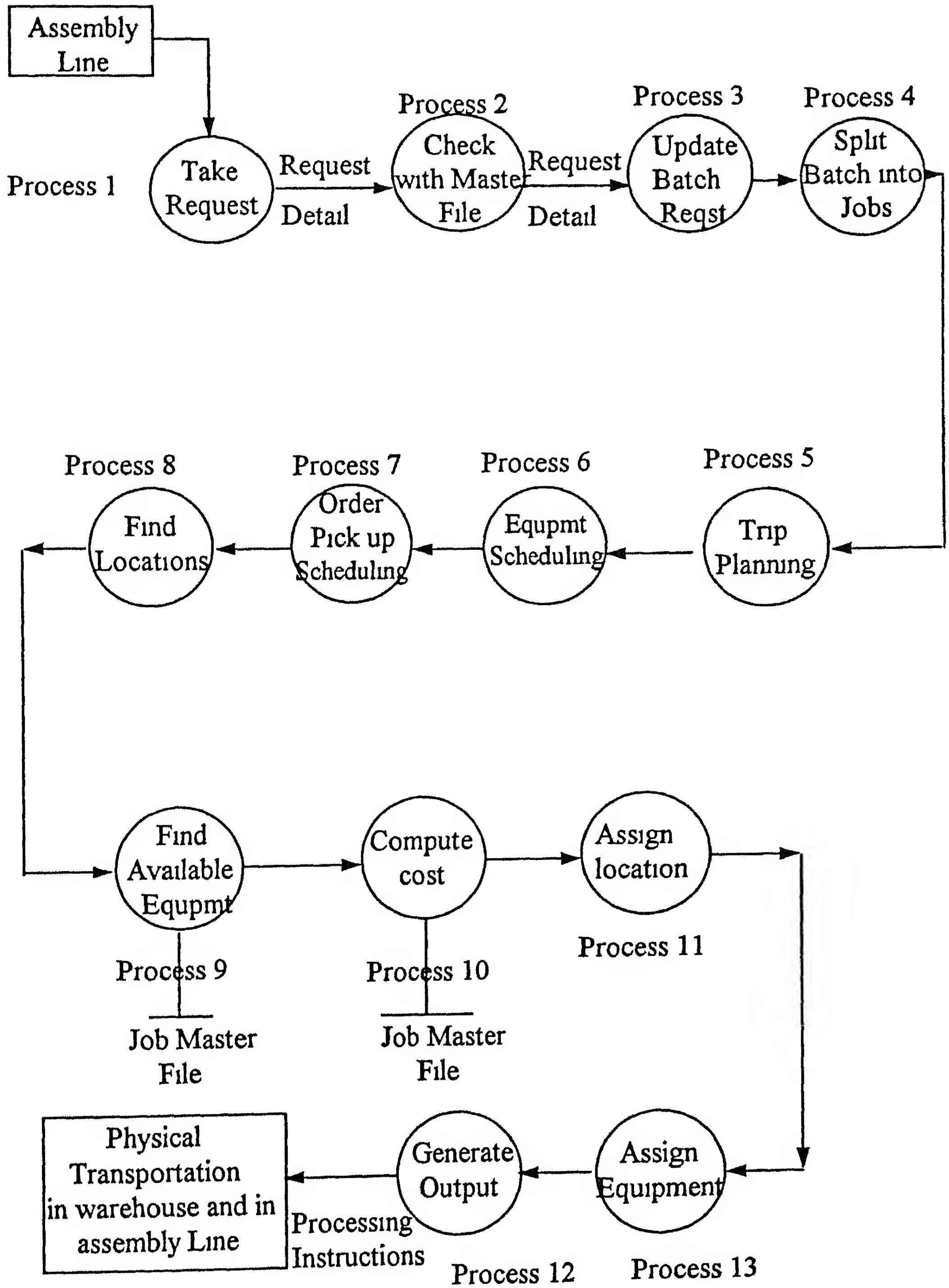

Fig 4.2 Detailed Data Flow Diagram

Process 8 : The functions of Process 5 are

- for each job in Process 4, find out the available locations in the warehouse from where items can be retrieved It can be done with the help of the file which has all the occupied locations of the warehouse
- to send details of available locations to Process 6

Process 9 : In this process following functions are performed

- for each location, found in Process 5, a list of available equipment is found
- This list of equipment id sent to process 7

Process 10 : The functions of this process are

- to compute the cost incurred either in storing an item to a given location, or retrieving an item from that location This cost is computed for each location and for each equipment in the list of equipment associated with that location
- This cost is computed according to the setting of various parameters and with the help of equipment characteristic data, stored in equipment file, location data stored in rack file, port data stored in port file, bin characteristic data stored in bin master file and product data in product master file
- to send the cost details to process 8

Process 11 : The functions of this process are

- to select the locations for different items listed in the request, depending upon the cost computed in Process 7
- to assign the selected locations to the items, listed in the request, and to store this assignment information in the job master file
- to send the location assignment scheme to Process 9

Process 12 : Following functions are performed in this process

- to assign various jobs, listed, to various equipment for retrieval
- to store this equipment assignment information in job master file and to send this scheme to Process 10

Process 13 : The functions of Process 10 are

- to generate the output of processing of the request which comprises of the locations and equipment assigned to each product in the request as well as the sequencing of execution of the request This sequence comprises the order of accessing different locations for each tour of each equipment All the processing is accomplished with the help of the job master file
- to generate a hard copy of the output, if desired by the user, to facilitate physical execution of the request by the warehouse personnel

4.1.2 Structured specifications of procedures

A brief description of the procedures, involved in different processes, mentioned above, is given below for better understanding of the system The following description is given in simple English language, but in a little bit of structured form so as to facilitate easy conversion to any computer programming language

4.1.2.1 Procedure for Process 1

for each incoming batch requests do

take batch number, type of model, their quantity, date of starting

send details of the request to process 2,

endfor

4.1.2.2 Procedure for Process 2

for each batch request do

check in the batch master file,

if batch request is present in the request master file then

give message that this batch is already present,

else

send request details to process 3,

endif

endfor

4.1.2.3 Procedure for Process 3 :

for each request do

enter all the request details in the request received file,

endfor

4.1.2.4 Procedure for Process 4 :

for the specified model in the request do

check the model requirements file,

check the assembly station information file,

check the process duration information file,

send the parts requirement information to process file,

endfor

4.1.2.5 Procedure for Process 5:

for the each part requirement information do

check the bin capacity file,

find out the number of bins to be sent to the assembly line

make each bin transfer a job,

send the list of jobs to process file,

endfor

4.1.2.6 Procedure for Process 6 :

for the each job in the job list do

find out the list of equipment available,

assign the jobs on the equipment with low index,

send the requests to the process file,

endfor

4.1.2.7 Procedure for Process 7 :

for each request do

enter all the job details in the request received file

endfor

4.1.2.8 Procedure for Process 8:

for each item in the request do

check occupied rack file ,

if any location is available then

find out the list of available locations in the warehouse from occupied

rack

file,

else

put the job in wait queue,

endif

send the list of available locations to process 6,

endfor

4.1.2.9 Procedure for Process 9 :

if equipment is to be selected by the system then

    for each location available in the warehouse do

        find out the list of equipment available for the location,

        send the list of equipment to process 7,

    endfor

endif

4.1.2.10 Procedure for Process 10 :

for each location available in the warehouse do

    for each equipment in the equipment list for the location do

        find out the distance traveled by the equipment to access the location

with

        the help of distance function,

        compute cost incurred in the equipment movement,

    endfor

endfor

4.1.2.11 Procedure for Process 11 :

sort the locations in the ascending order of cost associated with them,

do until all the items are assigned to locations

    assign the location on the top of sorted list to the item,

    store this location assignment in the request received file,

    delete the selected location from the list,

enddo

4.1.2.12 Procedure for Process 12 :

```
if equipment is to be selected by the system then
        for each selected location for the items listed in the request do
                find out the most optimal equipment for the location selected,
                store this equipment assignment in the request received file,
        endfor
endif
```

4.1.2.13 Procedure for Process 13 :

```
for each item in the request do
        list all the jobs generated from the batch,
        list all the locations assigned for the item,
        list all the bins which are to be handled for the item,
        list all the equipment used for transporting the item,
endfor
for each equipment selected to execute the request do
        for each tour of the equipment do
                list the sequence of operation for the tour;
                list the starting time of tour,
        endfor
endfor
if user asks for a print of the output then
        print the output with all the details,
endif
```

4.1.3 Broad specification of data

The process discussed in the previous section require a large variety of data ranging from assembly stations to the warehouse Every resource of the warehouse needs to be identified clearly and uniquely to avoid any ambiguity It means all the resources should have a unique identification number attached to them which distinguish them from other members of the same class Bin types and rack types are required for illustration purpose Capacity of each bin for every product, capacity of each equipment for both working in the warehouse and for movement between assembly line and warehouse and capacity of each rack in terms of number of rows and columns are required to simulate the real system For static components, like assembly stations, racks and ports, location (x and y coordinates) is required for the computation of time taken to execute the request Horizontal and vertical velocities of every equipment are also required for the same purpose Operating cost and man power required for each equipment and loading and unloading time for each bin-equipment combination are to be specified to evaluate the cost incurred in executing a request A more illustrated form of data specification is given below

4.1.3.1 Data about batch

For unique identification of the batches, a code assigned for each batch For each batch, there is particular model number associated with it and the starting date of production of that batch at the first assembly station

4.1.3.2 Data about model

For unique identification of the model, each model type is provided with a specified code For each model, the part requirements for that model at various assembly stations is given

4.1.3.3 Data about assembly station

For unique identification of the assembly station, a code is assigned to each assembly station In addition, data for assembly station - product relationship such as minimum level of inventory for each of the part is maintained

4.1.3.4 Data about part

For unique identification of the part, typically, a code is assigned to each part Apart from code, name of the part is required for the illustration purposes To keep track of the stock level, at a given point in time, of the part in the warehouse, total quantity of the part is required.

4.1.3.5 Data about bin

Bins are broadly classified in some types The warehouse may have several bin of the same type. Each type of bin occupies a definite amount of storage locations and cannot be stored beyond a certain specified height But to uniquely identify a bin, a unique identification number has been given to each bin In addition, data for bin - product relationship such as a particular bin type can handle type of parts and quantity is also needed.

4.1.3.6 Data about equipment

A unique identification number for each of the equipment retrieval within the warehouse and for transporting from warehouse to the assembly line, cost of the equipment, capacity of the equipment, manpower required to operate the equipment, operating cost and the horizontal & vertical velocities of the equipment are data-bits which are maintained Data regarding the equipment relationship with bins such as type of bins it can handle and the loading and unloading time for a particular equipment - bin type combination is also needed

4.1.3.7 Data about storage location

A unique identification number has been given to each of the rack Type of the rack, number of rows and columns in a particular rack and its location in the warehouse are other required information

4.1.3.8 Data about port

A unique identification number, type of the port and its location in the warehouse are needed to identify a given port

4.1.4 Hardware and software requirements

As has been stated earlier, the motivation for the development of the system is taken from the warehousing problem of a large automobile company It has been found out that the company has around 7,000 items to be stored in the warehouse There are 5 types of bins in the warehouse and a few equipment to transport the items to and from the warehouse It has also been observed that the transaction of data is not too voluminous to be stored on an inexpensive PC and thus it is felt that a PC based solution would be more cost effective and beneficial Therefore, the system has been developed on an IBM compatible PC based on intel's 80486 architecture In order to make system readily adaptable, it is felt that using the Microsoft Windows environment will be more effective. The reason is that Windows environment provides an in-built Graphical User Interface (GUI) which greatly enhances the user-friendliness and interaction between the system and the user GUI provides graphical images, in the form of what are commonly known as icons, which are self-explanatory about their possible functions. Therefore, using GUI completely eliminates the need on the part of the user, to know how to operate the system and thus reduces the burden of being trained particularly for using the system. Keeping in view the above advantages of GUI, provided by Windows the warehouse information system is developed in Microsoft Visual Basic language which operates in the Windows environment This

language is chosen because it provides the necessary amalgamation of processing power of a traditional language, like C, and an in-built database manager which helps in fast and efficient processing of data, stored in the database Since the system is developed in Windows environment, the user should have Microsoft Windows loaded on one of the hard disks on his/her PC Windows require a minimum amount of RAM of 4 MB

In essence, to be able to use the Warehouse Information System, the user should have the following at his / her side

- a PC 486 or higher version with one or more hard disks and atleast one external diskette drive
- Disk Operating System (DOS) version 5 0 or higher
- Microsoft Windows version 3 1 or higher loaded on one of the hard disk drives

4.2 System Design

4.2.1 Database Design

The "warehouse - assembly line on-line Information System" requires a variety of data which includes data about parts requirements at various assembly stations for various types of models, various products to be stored in the warehouse, data regarding various equipment to be used in the warehouse for the purpose of transporting the products between ports and storage locations, data regarding all the bins used in the warehouse for the purpose of storing the products and data for all the ports which are used for receipt and delivery of the products In addition, data for all the storage locations available in the warehouse is also required The details of data needs for the system are given in Section 4 1 3 above but this data is to be put into a proper format so that access to the required data is fast and efficient In order to do that, different relationships among the data have to be worked out and data has to be normalized and

grouped together The normalized relations among various data components are listed below (key fields are in *italics*)

Model - Assembly station - Product relationship : *model number, assembly station no, product code,* quantity required

Assembly station - Product relationship : *assembly station no, product code,* min inventory level, available quantity

Model - Assembly station relationship : *model number, assembly station no,* process duration

Product : *product code,* product name, stock level

Bin : *bin id,* bin type, space reqd, maximum permissible height of storage

Product - Bin relationship : *product code,* bin type, capacity of bin

Equipment : *equipment id,* cost, capacity, manpower reqd, maximum accessible height, operating cost, horizontal velocity, vertical velocity

Equipment - Bin relationship : *equipment id, bin type,* loading time, unloading time

Rack : *rack id,* type, no of rows, no of columns, x and y coordinates

Rack occupied : *rack id, row no, column no,* bin id, product code, product quantity

Request Master : *request no,* type, incoming date and time, due date, execution port

Request received : *request no, product code,* product quantity, bin id, equipment id

Port : *port id,* type, x and y coordinates

As mentioned earlier also, all this data is kept in the form of tables in a database The structure of one of these is given in Table 4 1 with all the field names, types and maximum length of each field

4.2.2 Program flow chart

In this section, the entire computer program for the system is illustrated with the help of flow charts As mentioned in Chapter II and III, the due date computations and equipment scheduling from the warehouse to the assembly stations is described

through these flow charts Moreover, these charts can also be used as a reference tool to help the user in understanding the system in a much better way

Field Name	Field Type	Field Size
Equipment ID	String	8
Equipment Type	String	1
Operating Cost	Real	System Dependent
Horizontal Velocity	Real	System Dependent
Vertical Velocity	Real	System Dependent
Manpower Reqd	Integer	System Dependent
Accessible Height	Real	System Dependent

Table 4.1 Equipment Table

4.2.2.1 Due date computation

First, we will deal with the due date computation for the given batch schedule and the solution method for this due date computation is given in 2 2 Program flow chart for this is given in Fig 4 3

4.2.2.2 Equipment scheduling

The solution methodology for the optimization of equipment between assembly line and warehouse is described in Section 3 1 Program flow chart for this is given in Fig 4 4 The flow chart for the order pickup system has not been described here, interested readers are requested to look into Rohit Bansal [68]

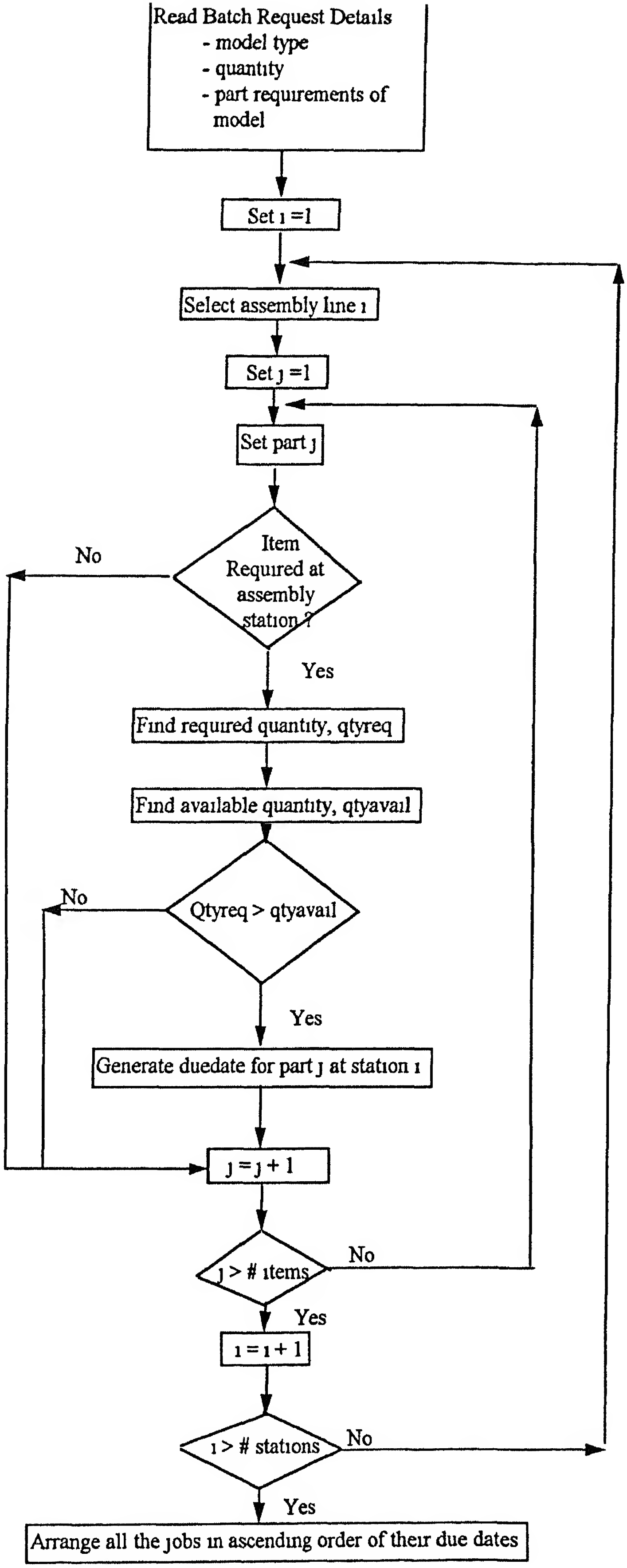

Fig 4.3 Due date computation

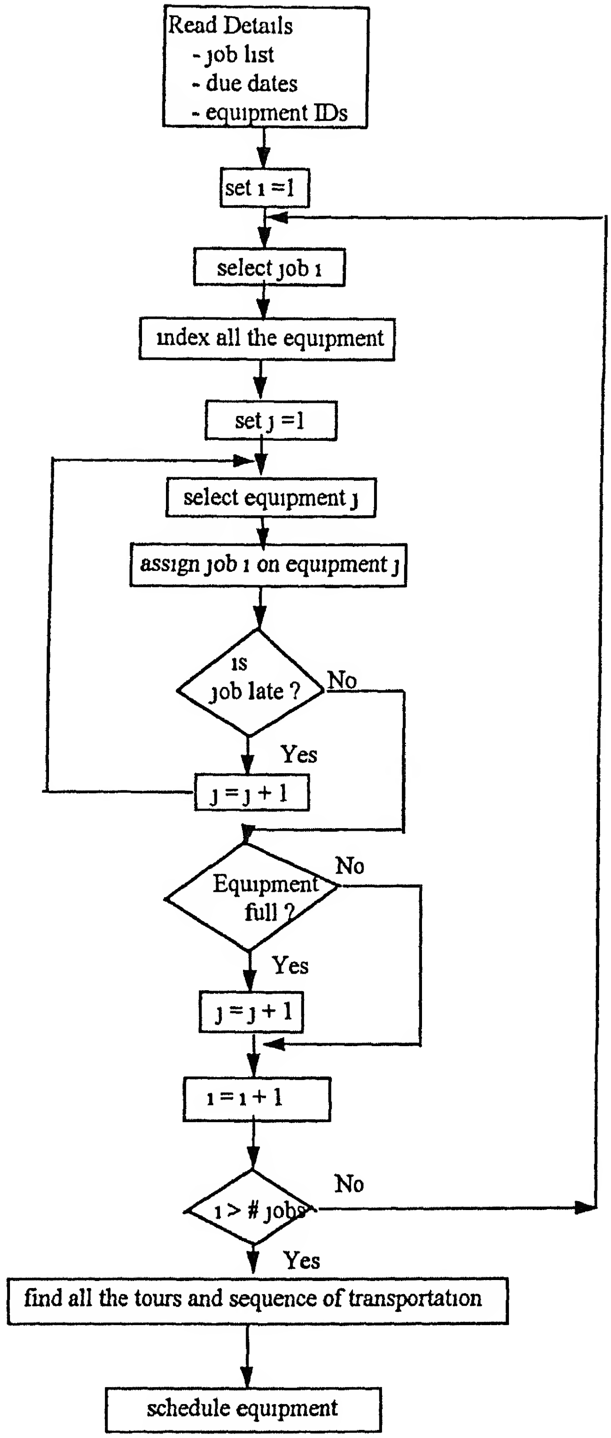

Fig 4.4 Equipment Scheduling

4.2.3 Data encoding for input

The system takes the input either in the form of some query or in the form of a request In the first case when the user asks for a specific query, input of data is in the form of the unique identification number assigned to that particular warehouse resource While submitting a batch request for the processing purpose, the user has to specify the model numbers, quantities of the listed models and starting date of the batch Apart from this, while initializing the database for a warehouse, the system requires all the relevant information about all the warehouse resources All the above information is entered in terms of data which is taken from the user in some encoded form, typically, in the form of numbers and text strings Following is a description of data formats required for each type of data used in the system

Text String : identification number of all resources and request number, batch number, model number, assembly station no, type of equipment, rack, bin and port, type of request

Numeric (real) : velocities of equipment, operating cost, accessible height, permissible storage height, location of ports and racks, loading unloading times, capacity of bin

Numeric (integer) : manpower reqd , number of rows and columns in a rack, capacity of equipment

4.2.4 Output Design

The format of the output generated by the Warehouse - Assembly line Information System, essentially, depends upon the input given by the user to the system If the input given to the system is in the form of a query, then the system displays the result of the query on the screen, along with all the relevant information, sought by the user, with proper labeling to enhance the legibility of the output The other case may be that the input to the system is in the form of a request In this case, the system displays all the information regarding the processing of that request on the screen for visual inspection This information typically, consists, of the data regarding the batch request

such as batch id, type of the model, quantity estimated for that batch and date of starting of that batch which are to be accessed for executing the request The system also provides the facility to take hard copy of the output of the batch request to facilitate physical execution of the request Also, a facility to monitor certain parameters of the warehouse and to take report of the performance of the warehouse on the basis of those parameters is provided Apart from these outputs, the system also generates following reports for managerial purpose

Model -Product requirement report: This is the information regarding the requirement of the products at various assembly stations for different models It helps the manager in keeping a close watch over the inventory requirement at the various assembly stations

Assembly station - Product report : This is the information regarding the minimum inventory level and the available quantity of various parts required at that assembly station This will give the warehouse manager, a view of the requirement of various parts at assembly stations and their demand

Stock level report : This is the information regarding the stock level of all the products in the warehouse for the purpose of inventory management It helps the manager in keeping a close watch over the inventory level of products in the warehouse so that orders for different components can be placed to different vendors at proper time to avoid any crisis

Job details report : This is the information regarding various trips of the equipment which were generated by the system for transfer of parts from the warehouse to the assembly stations for a batch This information can be retrieved for a particular batch or for all the requests

Request detail report : this report provides a detail description of any request submitted to the warehouse for processing It gives all information about request such

as request number, their quantities, bins handled, equipment used for transporting items, port involved in processing, time taken in processing of the request and the most important thing current status of the request Primarily, this report is used for record keeping purposes

Report for delayed requests : the user can generate reports regarding the request details for all those requests which have been delayed either because of non-availability of the product in the warehouse or because of equipment being not available at the time when request is submitted for processing These reports will be able to help the warehouse manager to find out the bottlenecks in the functioning of the warehouse, if any, and to manipulate the existing resource in the warehouse in such a way so as to meet the requirements of assembly line

Warehouse status report : this provides the information regarding the current status of the warehouse at the time of taking it It gives the information of various locations at which the products are stored at that instance, the status of each equipment of the warehouse, which bins are currently present in the warehouse and what are their contents In essence this report provides some sort of snapshot of the warehouse at the time when it is asked for

CHAPTER V

USERS GUIDE

Thıs chapter provıdes the user, all the necessary ınstructions to use the Integrated Warehouse Plannıng System (IWALRS) Here, ıt has been assumed that the user ıs well versed wıth the mouse techniques such as clıckıng and double clıckıng In case, user ıs not very comfortable wıth the mouse techniques, he / she ıs referred to Mıcrosoft Wındows User's Guıde In the followıng text, apart from ınstalling the system on a hard dısk drıve, varıous menu systems has been descrıbed ın detaıl for better understandıng of the functıonıng of the system

5.1 Installing IWALRS

To install and use the Integrated Warehouse Plannıng System (IWALRS), followıng equıpment and hardware ıs needed

- any IBM PC or compatıble with an 80486 mıcroprocessor or hıgher
- a minimum of 4 Mb RAM, for better performance
- an external or ınternal hard dısk drıve
- MS-DOS versıon 5 0 or hıgher and Mıcrosoft Wındows version 3 1 or hıgher already ınstalled on the hard dısk drıve of the PC DOS versıon 6 0 ıs recommended

In order to ınstall IWALRS on the hard dısk drıve, ınsert the dıstrıbutıon dısk ın the external dıskette drive and start Windows Go to the program manager's Fıle menu and select Run command from there A dıalog box wıll appear on

the screen to enter the command you want run Enter a setup and press the return key Here a is the name of the drive in which the distribution disk is inserted If the drive is something other than a then give the appropriate name in place of a

5.2 Menu System

WIS provides a wide range of options for the user to select from The main menu provides 7 choices namely Warehouse, Process, Evaluate, Query, Print, Options and Help and is displayed as shown in figure These choices are described in detail in the text follow

5.2.1 The Warehouse Menu

The Warehouse pull down menu offers many choices to the user for a variety of use It provides options to open and close the warehouse database, a whole set of pull down menus for maintenance work and start data option to enter existing warehouse data into the system for the first time And last but not the least, exit option to shut down the system

Open

This is used to open a database to store all the information regarding all the resources like products, bins, equipment, racks and ports of the warehouse The database stores the data regarding the functioning of the warehouse as well When this option is chosen, a file dialog box appears on the screen and asks for the name of the database to be opened If the user enters a database name which does not exist then it asks the user whether to create a new database or not In case of confirmation of the creation of a new database, it creates a new database for the user with no data, whatsoever, in it

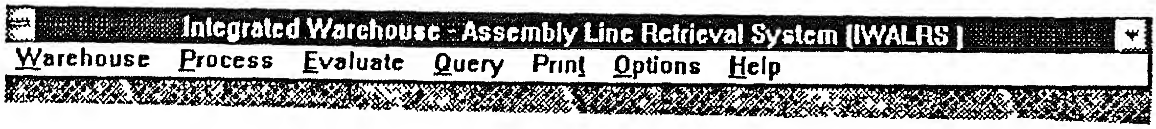

Fig 5.1 Main Menu

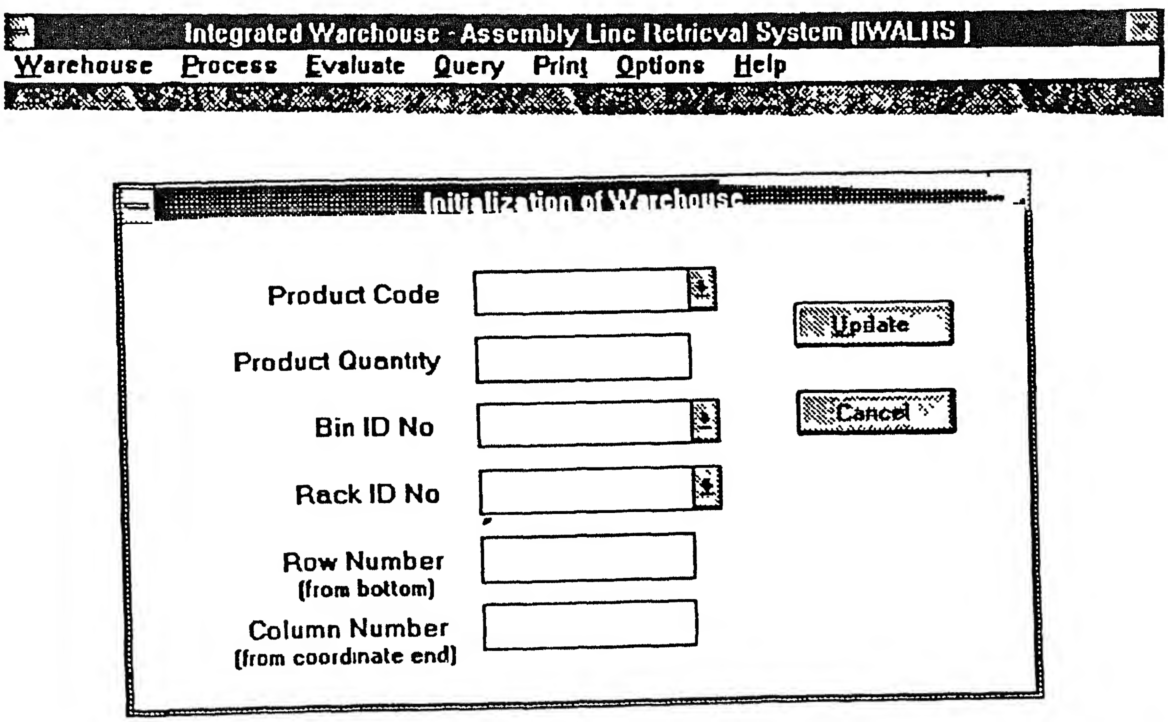

Fig 5.2 Warehouse Intialization

Close

It simply closes the currently open database When selected, it asks the user to confirm the closing of the database On confirmation, the system does the necessary house keeping and closes the database

Maintenance

This menu option helps the warehouse manager in keeping the warehouse database up-to-date All the relevant data of a warehouse can be broadly classified into two categories -resource data and functional data Resource data is the data regarding the resources of the warehouse like products, stored in the warehouse, bins in which products are stored, equipments which are used for transportation, storage locations, parts requirements of the models at various assembly stations, minimum inventory level required for various products at various work stations etc Functional data refers to data regarding the requests received in the warehouse and the performance measurement data This menu item provides options to add or delete various warehouse resources In addition to these two, one more important sub-option clean-up has been provided, keeping in view the limited disk space of the PC This sub-option cleans up all the functioning data of the warehouse from the database but not the resource data The user is advised to use this sub-option time to time so that disk space is always available to the system Note that if this sub-option is selected it removes all the functional data which is irrecoverable Therefore user should ensure that before using this, all the necessary data has been hard-copied in the form of reports

While entering the data about product, bin and equipment, the user is asked to describe various relationships among them, in the form of data These relationships are also stored into the system as part of the resource data Here, note that when any of the three resources is deleted from the system with the

help of Delete sub option the all the relationship attached to that particular resource will also be get deleted from the system Therefore every time the user enters a new resource will also be get deleted from the system Therefore every time the user enters a new resource system into the system, the relevant relationships are also to be entered afresh

Start data

The start data option is one of the most useful options, which is provided so that the user can enter all the information of an existing warehouse into the system at the time of starting This option requires that the data about various resources of the warehouse exist in the system beforehand Therefore, if it is required to start the system afresh, first all the data regarding products, bins, work stations, individual bins, equipment, storage locations and ports is to be entered into the system with the help of maintenance option described above Next the existing status of the warehouse can be given to the system with the help of this option User should note here that this option can be used only once If it is tried to use more than once on the same database, the system reports data integrity error The data entry form for this option is shown in fig 5 2

5.2.2 The Process menu

The process pull down menu enables the user to submit batch requests to the system Whenever this option is selected a data entry window appears on the screen, as shown in fir 5 3, where the user can enter the required data for the batch request The user has to enter all the data about the batch request in the data entry window, such as batch identification number and the type of model In addition to this, for a batch request user has to enter the size of the batch

and starting date of the batch After entering the data for a request and pressing the execute button on the window, request is processed by the system and the output of the entered request is displayed on the screen in a window with all the relevany details A sample output is shown in Fig 5 4 In the data entry window, the user is provided with an "Execute" button If the user presses this button then the request is processed and the system data is updated accordingly In case this button is not selected then the request is automatically discarded and the system is restored to its previous state

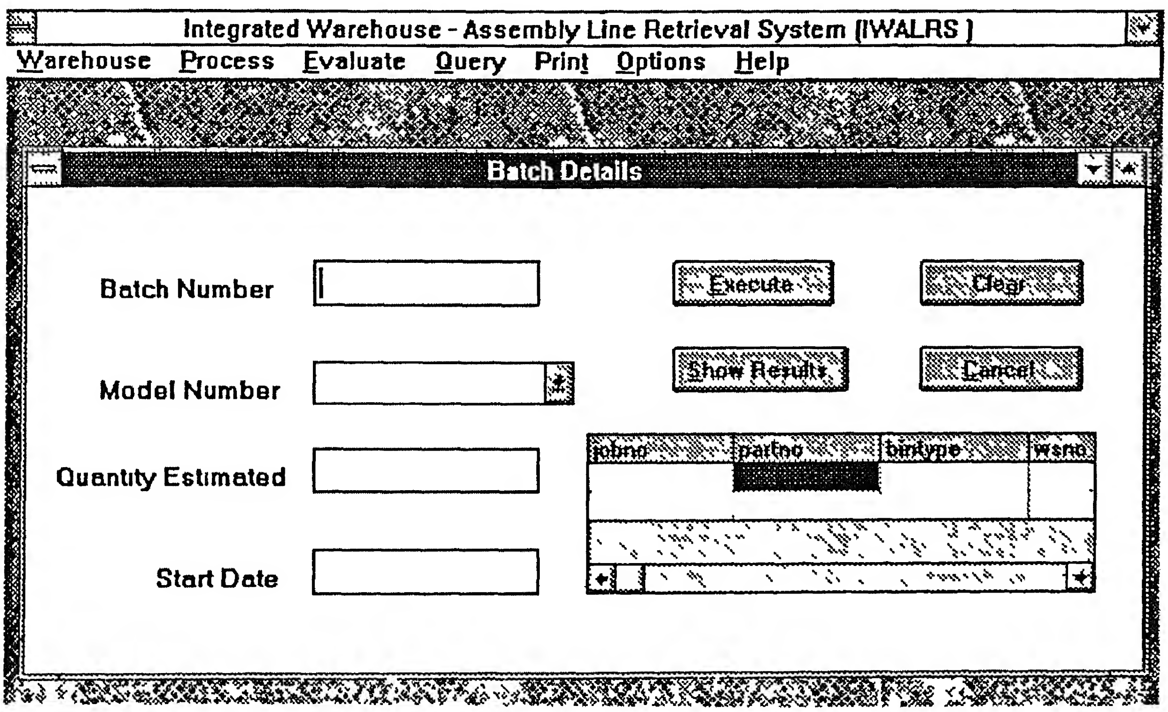

Fig 5.3 New Batch Request

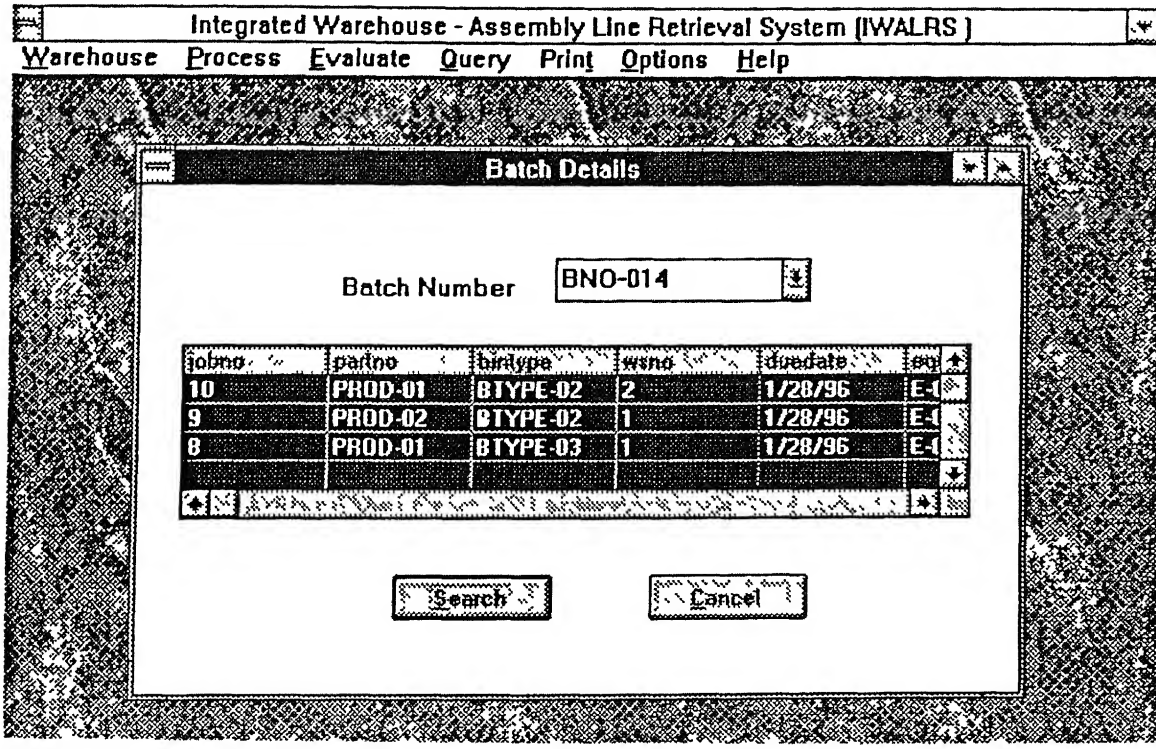

Fig 5.4 Output details of Batch

5.2.3 The Evaluate Menu

This menu item provides options to evaluate certain pre-defined warehouse performance measures such as rack utilization, equipment utilization, and product frequency When any of these options is selected the corresponding parameter is evaluated One important thing to note here is, that all the three performance measures are taken for a time period Therefore, evaluation of any of the parameter are not evaluated last till the time of selecting the option Also, these parameters are not evaluated by the system itself until and unless these options are selected by the user By transferring the power of evaluation of parameters to the user, the flexibility of the system has been increased

because, now the user can decide on the time interval of evaluating the parameters This enhances the adaptability of the system to different working environment Though, by doing this, the probability of missing some important data, because of the negligence on the part of the user, is increased

5.2.4 The Query menu

This menu item provides the user an interface by means of which information regarding all the resources of the warehouse can be sought at any point in time It provides options to make query for all the resources of warehouse such as product, bin, equipment, rack and port as well as options for request and output In all the options, the unique identification number of the resource, for which the information is required, has to be entered by the user In case of last two options, the corresponding request number is to be given by the system

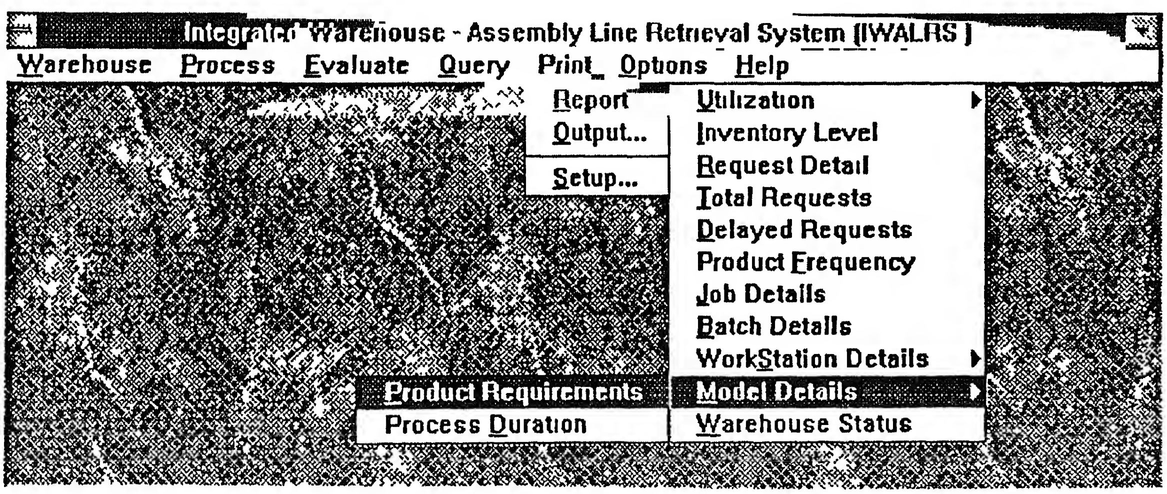

Fig 5.5 Print Menu

5.2.5 The Print menu

This pull down menu offers various options for printing the required documents useful for the record keeping purposes as well as for management information purpose All the options provided under this menu item are shown in figure 5 5 The options include option to print reports for decision making purposes, to print the output of a request and to setup the printer for user specific needs such as to change the fonts or style The report option includes various sub-options for different type of reports such as job detail reports of batches and utilization reports of equipment, report of current stock in the warehouse, all the details of a particular batch, a summary report of all the requests which have been delayed, report for frequency of different products and a report showing the current status of the warehouse User is advised to use this option for taking reports, before using the cleanup sub-option of the maintenance option in warehouse menu item, so as to take a hard copy of all the required data before all the data get deleted A sample report is shown in figure 5 6

5.3 Error Messages

The Warehouse Information System generates various error messages to indicate undesirable conditions which are generated by erroneous user input Though the messages given by the system to the user are self - explanatory, the various error messages and their possible reasons are given below

1]. Bin add error

This error is reported when an attempt is made to add a new bin into the system without any bin type being added The proper sequence is to add a bin type first and then add a bin into the system

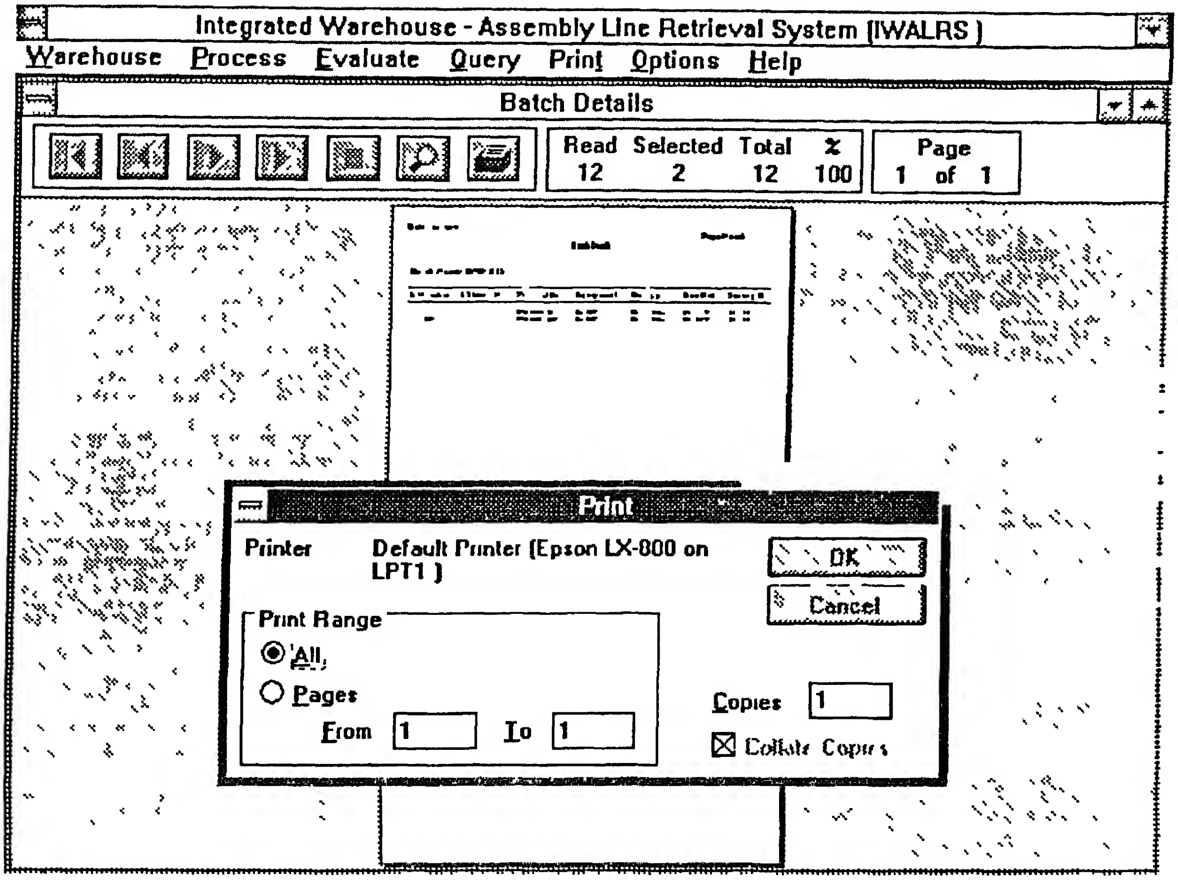

Fig 5.6 Sample Report

2]. Database not found

It is generated while using the open option of the warehouse menu for opening a database It occurs when the specified database is not found on the disk In strict sense this is not an error message as it is always reported whenever a new database is being created It simply signifies that the specified database is not present and the system is going to create afresh

3]. Data too large

It occurs when the user attempts to add some resource or submit a request to the system with the help of maintenance / add options with an identification number which is too large for the system to handle. The user is informed about

the upper limit on the size of the identification number with the error message so that rectification can be done accordingly

4]. Duplicate error

This error is generated by the system when the user makes an attempt to add some warehouse resource into the system, using the maintenance / add options, with an identification number which is already existing

5]. Incompatible database

This error is reported by the information system when the user specifies a database, not created by the system, in the open option of warehouse menu If the specified database is created by the system then it indicates that some damage to that database has been done through some other means It signifies that the specified database cannot be used by the system

6]Insufficient data

This error is reported by the system, when the start data option is used to enter the existing data of a warehouse into the system, without entering the data about all the resources The user should, first enter all the resource data into the system, with the help of the maintenance menu and then use the start data option

7]. Integrity error

It is reported when the user tries to enter some data into the system through start data option when data is already existing in the system This error signifies that an attempt is made to destroy the integrity of the system The user is advised not to attempt entering data into the system through this option when the data already exists

8]. Invalid file extension

This error is reported when user attempts to open or create a database with a file extension other than "mdb" The default setting of this extension in the

system is "mdb" and user is advised not to give any other extension Same error is reported if the user enters a file extension other than "dbf" while using the option Product mix commonalty index in the Options / Environment dialog box Here the user is asked to enter the name of a dBase which is having the product mix data

9]. Item not found

This error is generated while querying the system for any of the resources or the request It usually occurs when the user presses the "Search" or "Delete" button in the dialog box without specifying the identification number of the item being queried

10]. Type mismatch

This error is reported at the time of entering data into the system It indicates that the data type which is entered by the user is not of the type which is expected It occurs, typically, when some numeric data is expected and the user attempts to enter data in character form

11]. Utilization error

It occurs when the user attempts to evaluate either equipment utilization or rack utilization through evaluate menu item It signifies the absence of the related resource data into the system The user should first enter the resource data into the system and then use this menu item to evaluate the desired parameter

CHAPTER VI

MODEL SEQUENCING

In this chapter we shall examine the impact of the model - batch sequencing on the material handling equipment requirement generating all possible sequences was conducted First, we will conduct a trial study to see, if there is any such impact

6.1 Impact of batch sequencing on the material handling equipment requirement

The developed system has been used to test some practical problems which motivated this dissertation Throughout this dissertation we have assumed that the production plan is available and based on that production plan due-dates were generated To examine the impact of the model batch sequencing in a trial study with two examples in a four week production schedule has been studied and material handling equipment problem is studied for one sequence generated on maximum common part rule and remaining sequences are randomly generated sequences of these batches In this, one example has models using 100 various parts at various assembly stations and another has 200 parts using at various assembly stations For test problems requests are generated either randomly (R) or using maximum common part rule (C)

Example one (With 100 products) **:**

Week	No of Models	Rule	Batch Sequencing	No of Trips / Machines			
				Fork Lift		Trolley	
Week 1	4	R	2 3 4 5	44	9	33	6
		R	5 2 4 3	41	9	33	6
		R	4 2 5 3	39	9	35	6
		C	3 5 2 4	33	7	31	5

Week 2	3	R	1 3 4	38	8	25	5
		R	4 3 1	27	8	26	7
		R	4 1 3	34	7	25	6
		C	3 1 4	28	6	22	5
Week 3	6	R	1 2 3 4 5 6	18	6	37	7
		R	4 3 2 6 1 5	21	8	45	8
		R	3 5 2 1 6 4	19	7	41	8
		C	6 2 4 5 1 3	28	6	32	5
Week 4	2	R	1 6	34	8	11	2
		C	6 1	34	8	10	2

Table 6.1 Example 1

Week	No of Models	Rule	Batch Sequencing	No of Trips / Machines			
				Fork Lift		Trolley	
Week 1	4	R	2 3 4 5	39	9	63	8
		R	5 2 4 3	47	8	47	8
		R	4 2 5 3	48	9	52	8
		C	3 5 2 4	50	8	55	7
Week 2	3	R	1 3 4	39	9	45	7
		R	4 3 1	30	10	38	6
		R	4 1 3	33	9	42	6
		C	3 1 4	35	8	43	6
Week 3	6	R	1 2 3 4 5 6	34	6	60	6
		R	4 3 2 6 1 5	31	8	53	5
		R	3 5 2 1 6 4	35	9	58	6
		C	6 2 4 5 1 3	37	8	62	4
Week 4	2	R	1 6	35	6	28	6
		C	6 1	40	5	25	5

Table 6.1 Example 1

It can be observed that the production plan has a considerable effect on the number of machines (fork lifts and trolleys) required and here the sequence following the maximum common component rule (C) seems to give better results This fact motivates the need for generating effective production plan which minimizes the

resources (fork lifts and trolleys) required It may be noted that the due-date of the jobs i e the time at which the material is required at the stations will depend on the structure of the model, lot size and the available inventory at the stations

CHAPTER VII

CONCLUSIONS AND FUTURE SCOPE FOR WORK

7.1 Conclusions

In this dissertation an attempt has been made to develop a warehouse - Assembly line retrieval system which can help in efficient functioning of the production system In the system, the problems, namely due-date calculation, material handling equipment scheduling and order pick up have been dealt with In this both fork lift and trolley truck cases are considered In this system, whenever the production schedule for a batch comes, the requirements of the batch are split into number of jobs and this data is fed to the warehouse for retrieval purpose In the system several parameters have been used to simulate the actual working conditions of a warehouse The system is equipped with all the necessary user interface so that the user can have total control on the system This interface vary from simple messages to much more complicated data entry windows which guides the user in interacting with the system The system also provides all the necessary documents in printed form which will surely make the system more adaptable to an organizational environment The system has been developed in Windows environment, which, definitely, will be a great advantage for the user in handling and using the system for his / her purpose because Windows provides an excellent graphical user interface which renders the training for using a new system, unnecessary

7.2 Future scope of work

As mentioned above, three major problems have addressed in this dissertation In all these problems, some simple heuristics have been used to arrive at the results. The

solutions given by these heuristics, obviously, will not be the exact optimal solution of the problem Therefore, there is an ample scope for improvement at this front so that the solutions yielded by the system can become more near to the exact solutions The system has been developed in a modular way so that the modified solution methodologies for different cases can be plugged into the system without much of problem This system does not incorporate the clustering of orders at the time of retrieval which may be one of the additions to the system

One of the limitations of the present system is that at the time of retrieval, at a time one stock keeping unit is moved which in the present system is assumed to be a bin Therefore, by making a provision for the movement of an item itself, this assumption can be relaxed to make the system more realistic

In addition to the above possibilities, there is a scope to integrate the system vertically with an automated retrieval system which will retrieve the items of the request from the locations decided by the developed system and in a sequence determined by this system This system can also be integrated horizontally with an automated receipt and dispatch system so as to fully automate the entire warehouse operations

One more possible extension of the present work may be to integrate an inventory control module to the present system as the system already keeps track of the stock level of all the products in the warehouse

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